§24. Preliminary Investigation of a Quasi-Axisymmetric Configuration Optimized for Contours of the Second Adiabatic Invariant

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Improvement of collisionless alpha particle confinement is one of the essential issues in the optimization of the stellarator configuration. Theoretically, this can be achieved by closure of contours of the second adiabatic invariant J within flux surfaces. J is defined by a line integration of parallel velocity of a trapped particle along the particle orbit,

$$J(s,\theta,\phi) = \int v_{\parallel} dl, \quad (1)$$

where s is a flux surface label and θ and ϕ are poloidal and toroidal angles in Boozer coordinates, respectively. Recently this concept has been employed in the configuration optimization of the Wendelstein 7-X, in which J contours are made closed poloidally, $J(s,\theta) = J(s)$.[1] It has also been applied to LHD-like configuration.[2] In this fiscal year we began to explore the possibility of the further optimization of a quasi-axisymmetric (QA) configuration by applying this concept. In the QA case, $J(s,\phi) = J(s)$ must be satisfied as far as possible. We have successfully installed the necessary code package into the NIFS supercomputer. The package consists of the equilibrium code VMEC2000, the configuration optimizer, and the guiding center orbit code for the evaluation of the actual alpha particle confinement.

Figure 1 shows the topview of the J contours drawn in the torus equatorial plane for a QA configuration called 2b32m3, one of the reference configuration for a compact QA stellarator. Major radius is normalized to unity and minor radius is enlarged to 0.8 for all toroidal positions in Fig. 1. The contours are not drawn in the inboard side of the torus, where there is no trapped particles. As shown, the contours are largely deviated from concentric ones, which indicates that the alpha particle confinement is not so good. Radial profiles of the maximum and minimum values of J in each flux surface are shown in Fig. 2. The large difference between $J_{\max}$ and $J_{\min}$ means that trapped particles can escape easily towards the edge region due to the J invariance. In contrast, $J_{\max} = J_{\min}$ everywhere in the equivalent tokamak case, due to real axisymmetry.

The optimizer runs so as to minimize "penalty function" which can be customized in the code. First we used a penalty function to close J contours in the (s,ϕ) plane as far as possible. As a result, the penalty function itself was reduced less than one-fifth of the initial value. However, actual alpha particle confinement calculated by the orbit code was not improved in spite of the reduced penalty function. We are now trying a new function so as to satisfy $J_{\max}(i) < J_{\min}(i-1)$ as far as possible in order to prevent trapped particles from escaping toward the edge, where i is the number of flux surface. According to a preliminary calculation, we could obtain a further improved configuration with better actual alpha particle confinement.

References

1) Mikhailov, M. I. et al.: Nucl. Fusion **42** (2002) L23.

2) Isaev, M. Yu et al.: Nucl. Fusion **43** (2003) 1066.

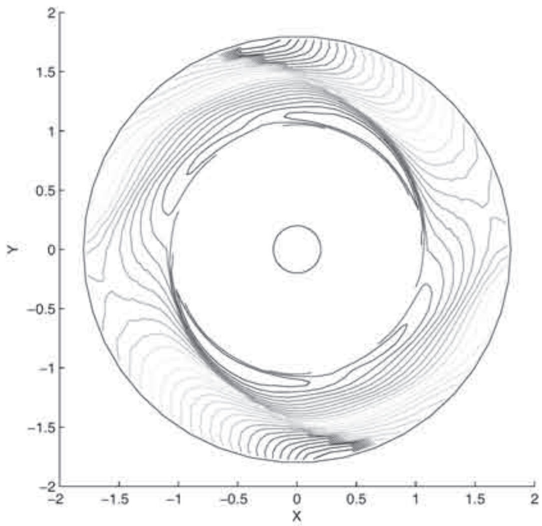

Fig. 1. J contours drawn in the topview of the torus equatorial plane for a reference configuration (called 2b32m3) of a QA stellarator. Major radius is normalized to unity and minor radius is enlarged to 0.8 for all toroidal positions.

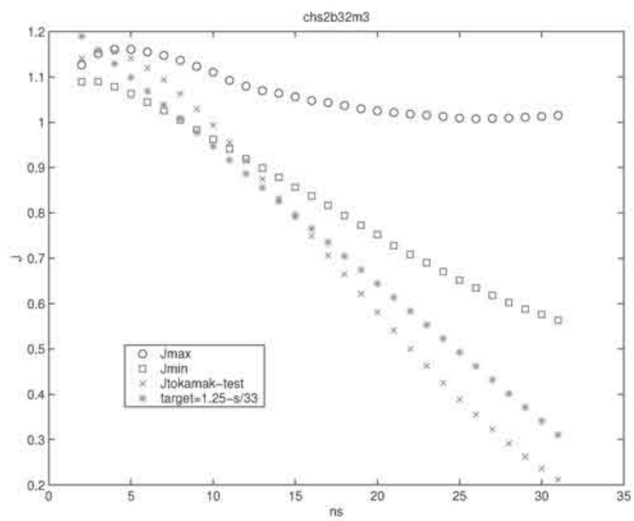

Fig. 2. Radial profiles of the maximum and minimum values of J in each flux surface for the same configuration as Fig. 1. Times symbols show the radial profile for the equivalent tokamak.