§53. Physics of Modular Heliotron

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Recently, modular heliotron system with clean divertor was proposed[1]. We analyze the configuration properties of modular heliotron by using three-dimensional equilibrium code VMEC. Figure 1 shows the comparisons of the finite beta deformation of magnetic surface at $\phi = 0°$ with conventional heliotron, reference modular heliotron and improved modular heliotron. The conventional heliotron correspond to continuous coil system. The reference and improved modular heliotron mean without and with plus/minus pitch modulation. This figures are at marginal beta limit for equilibrium. These equilibrium beta values are determined by the criteria on the conversion of VMEC calculation or the large outward shift of plasma axis (beyond 0.6 of normalized plasma minor radius). The conventional heliotron (Fig.1(a)) is well optimized by the inward shift of 15cm which is the results of LHD optimization. The equilibrium beta limit is about 10%. The magnetic surface of reference modular heliotron is deformed to the rectangular shape instead of the elliptical shape, which reduces the equilibrium beta limit to $\sim$ 4% (Fig.1(b)). One of the reasons on the decrease in the equilibrium beta limit is the existence of the wide shear-less region in the plasma core. As for improved modular heliotron, the beta limit is greater than 10% (Fig.1(c)). Figure 2 summarized the results of equilibrium central beta limit as a function of modular coil gap. In this figure the improvement of the equilibrium beta and particle confinement by the plus/minus pitch modulation technique is clarified.

We analyze min-B contour for estimating the confinement of deeply trapped particle. The conventional heliotron has good particle confinement properties. On the other hand, the magnetic surfaces do not coincide with the min-B contours in the reference modular heliotron. In the improved modular heliotron, the outer magnetic surface nearly agrees with outer contour of min-B. However, different from the conventional heliotron, the central min-B contour is deformed due to the bumpy component of magnetic field. Aside from $m = 0/n = 10$ bumpy field components. other field components are almost same between the conventional heliotron and the improved modular heliotron.

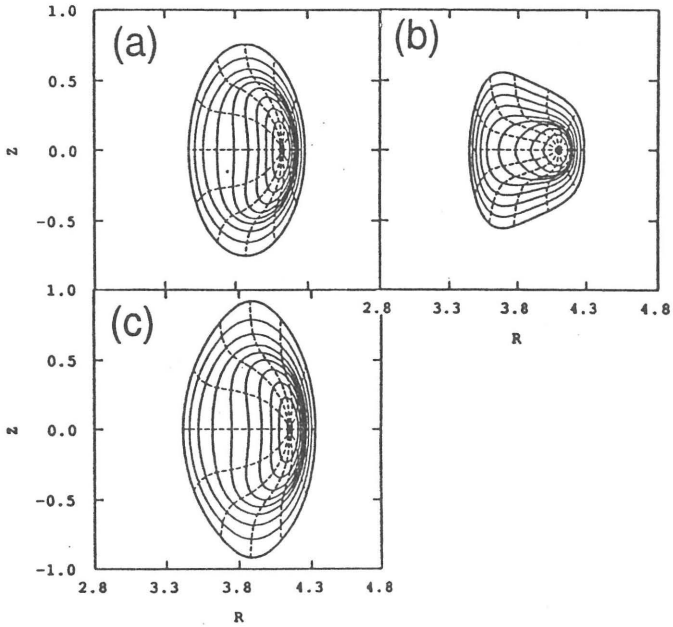

Fig.1 Magnetic surfaces at nearly equilibrium beta limit. The central β_0 defined by the external field strength at he machine center R_0 is used.

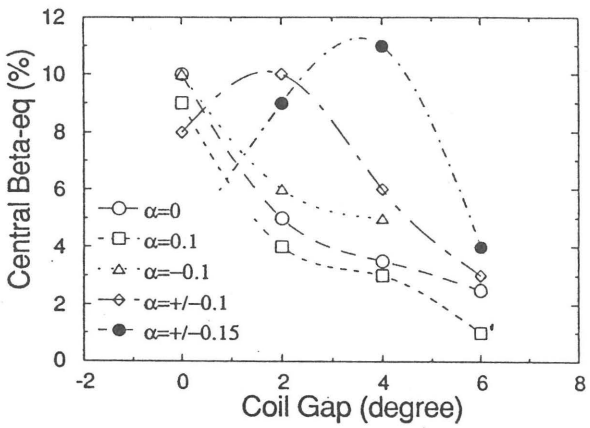

Fig.2 Effect of modular coil gap on equilibrium beta limit. Gap zero corresponds to conventional heliotron. $\alpha = +/-$ corresponds to improved modular heliotron.

[1] K. YAMAZAKI: J. Plasma and Fusion Res., 70 (1993) 281.