§15. Numerical Calculation of MHD Equilibria Including Static Magnetic Islands in a Straight Heliotron Configuration by Means of a Field Line Tracing Method

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In order to study the effect of the static magnetic island on the behavior of the interchange mode, we have developed a numerical code to calculate an equilibrium with the pressure profile consistent with the island geometry, particularly, the profile which is locally flat at the O-point and steep at the X-point[1]. The equilibria corresponding to the reduced MHD equations and a straight LHD configuration are obtained. The numerical scheme is composed of two steps solving the pressure and the poloidal magnetic flux. They are iterated until the island width is converged. In the step for the pressure, a field line tracing method is employed to solve $\mathbf{B}\cdot\nabla P = 0$. In order to obtain a solution with a finite pressure gradient at the X-point, we start the field line tracing at the azimuthal angle corresponding to the X-point and replace the pressure along the field line with the value at the initial point. In the step for the poloidal flux, we utilize a relaxation method for the coupled equations composed of the Ohm's law and the vorticity equation. The poloidal flux is obtained when a steady state in these equations is achieved.

Figure 1 shows the pressure profile of the resultant equilibrium. The comparison with the magnetic surfaces shown in Fig.2 shows that the pressure is flat in the inside of the island while the pressure gradient is finite at the X-point. Figure 3 shows the island width for the cases of the vacuum and $\beta_0 = 1.5\%$. The static island is generated by the external poloidal flux. Therefore, the island is increased as the external flux at the plasma edge Ψ_b is increased in the vacuum case. In the finite beta case, the width is also increased and enhanced by the finite beta effect. Furthermore, the increment is also increased with Ψ_b.

On the other hand, we also obtain another kind of solution with a locally flat pressure profile at the X-point by utilizing a different method with Fourier series[2]. Thus, there exist two kinds of equilibrium solutions depending on the pressure gradient at the X-point, finite or zero. The difference of the equilibria is related to the continuity of the pressure gradient at the separatrix of the island except the X-point. The gradient at the X-point can be finite in the case where a discontinuous pressure gradient is allowed, while the gradient at the X-point must be zero in the case where only a continuous pressure gradient is allowed.

1) K. Saito, K. Ichiguchi and R. Ishizaki, Plasma Fusion Res. **7**, 2403032 (2012) .

2) K. Saito, K. Ichiguchi and R. Ishizaki, Plasma Fusion Res. in print (2012).

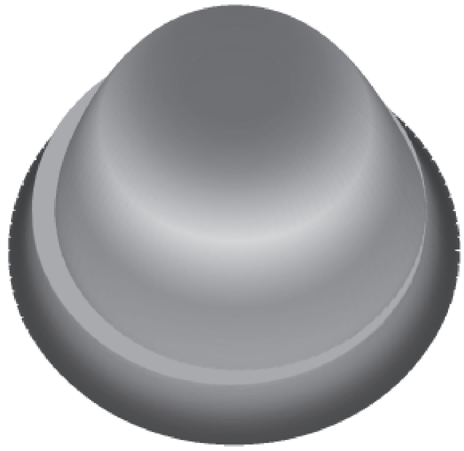

Fig.1 : Bird's eye view of equilibrium pressure profile at $z = 0$ cross section for $\beta_0 = 1.5\%$ and $\Psi_b = 1.0 \times 10^{-3}$.

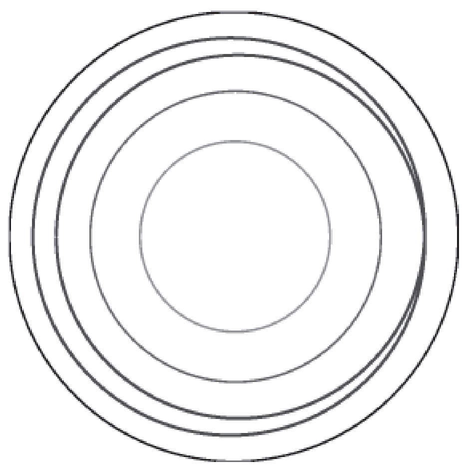

Fig.2 : Magnetic surfaces corresponding to Fig.1.

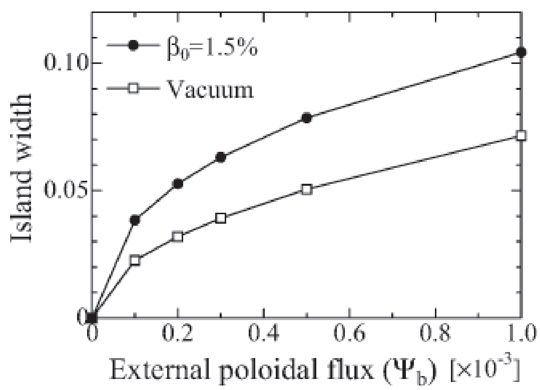

Fig.3 : Dependence of equilibrium island width on Ψ_b.