§14. Low Beta MHD Equilibrium Including a Static Magnetic Island in a Straight Heliotron Configuraion Obtained with a Parallel Diffusion Equation

Saito, K. (Grad. Univ. Advanced Studies),
Ichiguchi, K., Ishizaki, R.

An MHD equilibrium including a static magnetic island for the reduced MHD equations at $\beta_0 = 0.16\%$ is obtained in a straight heliotron configuration[1]. The equations to be solved are the coupled equations for the poloidal flux Ψ and the pressure P. In the formulation, the Fourier expansion is employed and the static island with $(m, n) = (1, 1)$ is treated. The equations are solved by iterating two numerical steps. In the first step, the equation of $\mathbf{B} \cdot \nabla P = 0$ is solved with the poloidal flux fixed so that the pressure constant along the field line is obtained. In the present study, we utilize a diffusion equation parallel to the field line to solve this equation. The steady state solution of the diffusion equation corresponds to the pressure constant along the field line. Three Fourier components of $P_{0,0}, P_{1,1}$ and $P_{2,2}$ are necessary at least to obtain the steady state. In the final equilibrium pressure, $\hat{P}_{2,2}$ is negligibly small compared with other components at $\beta_0 = 0.16\%$, and therefore, it is not necessary in the second step. In the second step, the force balance equation for the poloidal flux, which is derived from the vorticity equation, is solved with the pressure fixed. Since $\hat{P}_{2,2}$ and higher pressure components can be neglected, the Fourier series of the equation is truncated up to $n = 1$. In this case, the condition of $\tilde{\Psi}_{1,1} = 0$ and an ordinary differential equation for $\tilde{\Psi}_{0,0}$ are derived from the force balance equation. Therefore, only $\tilde{\Psi}_{0,0}$ is updated with the solution of the ordinary equation in the second step.

In the resultant equilibrium, we obtain a pressure profile which corresponds to the island structure as shown in Fig.1. A separatrix is seen also in the pressure contour plot, however, the pressure gradient is zero at the rational surface. That is, local flattening appears at not only the O-point but also the X-point as shown in the plot of $\kappa_\perp/\kappa_\parallel = 0$ in Fig.2. On the other hand, we also examine the effect of the pressure diffusion perpendicular to the field line in the first step. As the perpendicular diffusion coefficient increases, the pressure gradient is enhanced at the X-point as shown in Fig.2. A pressure profile flattened only at the O-point not the X-point can be obtained for a sufficiently large coefficient.

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

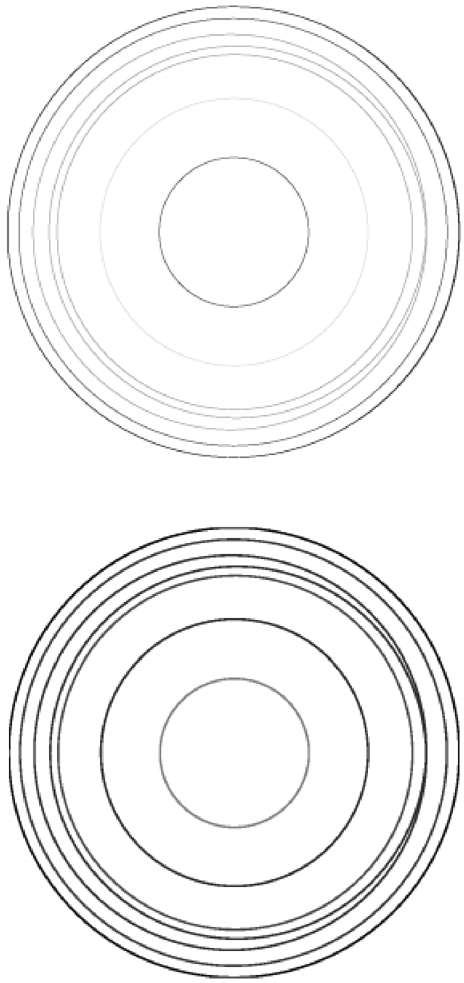

Fig. 1: Pressure contour (upper) and magnetic surfaces (bottom) of the resultant equilibrium at $\beta_0 = 0.16\%$ on $z = 0$ cross section.

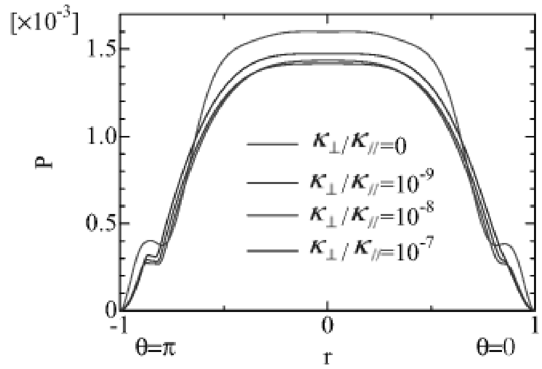

Fig. 2: Profiles of resultant pressure along the line connecting $(r = 1, \theta = 0, z = 0)$ and $(r = 1, \theta = \pi, z = 0)$.