§2. Full 3D MHD Equilibrium of a Rippled Tokamak

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In most of situations, tokamak equilibria are analyzed as axisymmetry (2D) systems. The nature of this symmetry gives many advantages for its analysis. However, as realistic tokamaks have discreteness of the toroidal field coils, this discreteness yields the toroidal field ripples (TF ripples) and, strictly speaking, realistic tokamaks could not be axisymmetric configurations. Here we define a rippled tokamak as a tokamak with the TF ripples.

Though the TF ripple is usually very small and can be neglected as a good approximation in many cases, it is considered to influence the confinement of the high energy particles, particularly, alpha-particles. The loss mechanism due to the TF ripple might yield severe heat loading on the first wall especially in a fusion reactor. A lot of studies have ever been made with respect to the TF ripple loss. However, many theoretical works did not take finite pressure effect into account. Most of more realistic TF ripple loss analyses using numerical solution of MHD equilibria are based on the axisymmetric equilibria obtained by solving the Grad-Shafranov equation, and particle orbits are calculated using a non-axisymmetric field which is obtained from the axisymmetric MHD equilibrium field superimposed the vacuum field ripple on it. Consequently, the conventional approach does not include the change of the non-axisymmetric magnetic field component due to the finite pressure.

On the other hand, in recent tokamak experiments, it is noted that stochastic filed lines reduce strong heat load driven by the edge localize mode (ELM) on the divertor plate. Stochastic field lines are produced by the external helical perturbation and it is called the Dynamic Ergodic Divertor (DED). From the viewpoint of high-β stellarator equilibrium, finite-β effects on the stochastic field are very important. However, in present analyses of DED, 2D MHD equilibrium superimposed vacuum helical perturbed field was still used. In order to consider effects of DED to ELM, the study of finite-b MHD equilibrium is a critical issue.

In this study, the fully three-dimensional (3D) equilibrium of a rippled tokamak is solved numerically and finite-β effects are studied. For this study, we use a 3D MHD equilibrium code HINT2, which does is widely used to analyze the 3D equilibrium of helical system plasmas.

Figure 1 shows a puncture map of magnetic field lines on an ITER-like tokamak configuration. Since HINT2 does not assume nested flux surfaces, the code can calculate the equilibrium with null points. In fig.2, q-profiled are plotted as the function of the normalized minor radius.

The study of the confinement of α-particle using this equilibrium and the calculation of DED are now in progress.

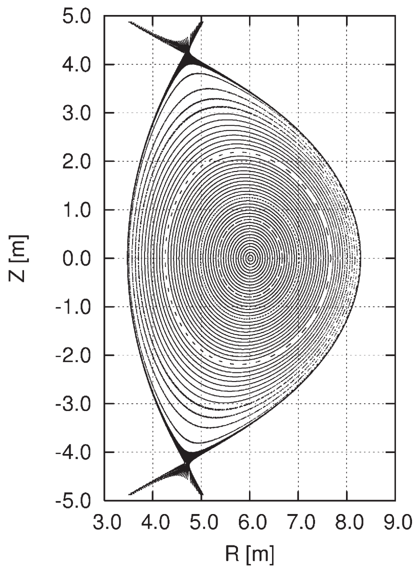

Fig. 1. Puncture map of magnetic field lines on an ITER-like tokamak

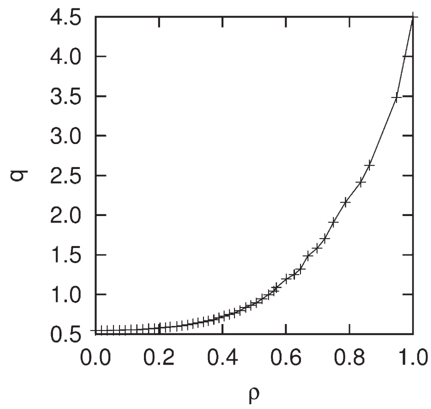

Fig. 2. q-profile of the ITER-like tokamak equilibrium