§1. HINT Computations and Nonlinear Simulations of Helical Plasmas

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In order to answer the question of whether or not a three-dimensional (3D) magnetohydrodynamic finite-beta equilibrium can maintain the integrity of its magnetic surfaces, a 3D equilibrium code, HINT, which does not a priori demand the existence of regularly nested magnetic surfaces [1,2], was developed. We have numerically analyzed island formation for the Heliotron [3-5], Helias [5,6], and Heliac [7] configurations using HINT. One important discovery obtained was that magnetic surfaces are broken by the finite pressure effect in an actual helical configuration, and the breaking often imposes severer limitation on the equilibrium beta than the Shafranov shift. Also, we have found that the way islands appear for each configuration is pretty much different to each other. In the process of equilibrium calculation, we found one remarkable property of magnetic islands induced by the finite pressure effect: the islands, in some cases, show a property of 'self-healing' in that they tend to shrink as beta increases [6].

We analyze the consistency of the equilibrium on the rational magnetic surface 5/6 which exists in the Helias configuration for vanishing island thickness. We find that the plasma deforms itself so that the so-called Hamada condition, that $\int dl/B$ be constant on a rational surface, is satisfied with very good numerical accuracy when the island vanishes completely due to self-healing. The behavior described above for a Helias configuration occurs with the resistive interchange criterion being satisfied. The importance of the global effect is further confirmed by a computation for resistive-interchange unstable equilibria; we observe the similar process of the self-healing.

We have considered linear analyses and nonlinear simulations of pressure driven instabilities in a helical device. Nonlinear simulations in a full 3D geometry of a helical device, as addressed in this study, have seldom been attempted until now. As a first approach, we study an H-1 Heliac configuration, which is characterized by the low magnetic shear. In the nonlinear simulations, we solve compressible full 3D MHD equations. As β is gradually increased by an assumed heating source term in the pressure equation, unstable modes are excited [9].

Nonlinear simulations show that pressure driven modes act as barrier against an attempt to increase beta, and cause a deformation and redistribution of the pressure profile. In the linear phase of development, the property of the excited modes are consistent with the linear prediction. In the nonlinear phase, however, many modes are excited simultaneously, and strong coupling between those modes occur, thus the pressure profile for those modes becomes complicated. The peak beta value decreases gradually. What should be noted is that after some time, all the modes once excited become stable, and the overall pressure profile is smoothed and becomes broader.

In a nonlinear simulation for a broader initial pressure profile, we observe a low-n external-type mode predominantly evolves, where the deformation is localized in the bad curvature region, mainly in the outer side at the toroidal angle with the outer excursion of surfaces.

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