§6. Nonlinear MHD Simulation of Helical Plasmas

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We have studied many cases of plasma relaxation phenomena by using magneto-hydrodynamic (MHD) computer simulations so far, and have found that the processes are often well described by what is called the Taylor's relaxation theory. When those cases are carefully examined, however, they are the relaxation phenomena that are driven by current-driven instabilities, and the role of the plasma pressure is not important. In the Taylor's theory, it is known that the role of the plasma pressure is neglected. A guiding principle of a relaxation process which includes possible effects of the plasma pressure has not yet been known. The basic motivation of this study is to see how a relaxation process is when the plasma pressure plays a predominant role. For this purpose, a helical system plasma is a good target to be studied. This is because the most part of the free energy of a plasma is stored in the form of the pressure energy, rather than the current energy, especially in net-current free equilibrium of a helical plasma. For a helical plasma, linear analyses actually show that the most relevant instabilities are usually pressure-driven instabilities, like the interchange mode and the ballooning mode, rather than current-driven ones. In addition, in the experiments of helical devices, processes which are considered to be energy relaxation phenomena have been observed. Therefore, it may be interesting to investigate nonlinear time development of such relaxation phenomena observed in helical plasmas by using MHD computer simulations, through which a "new" guiding principle of plasma relaxation phenomena could be hopefully extracted.

With this motivation in mind, we execute linear analyses and nonlinear simulations of pressure driven instabilities in a helical device. A nonlinear simulation code has been developed based on the framework of the HINT code [1], which is a three-dimensional equilibrium code using an initial value method. The main characteristic of HINT is that it does not demand the existence of nested flux surfaces. It has been applied for several kinds of helical configurations, like heliotron, helias, and heliac, and has revealed important natures of island formation in finite pressure three-dimensional plasma equilibria, including the discovery of the "self-healing" phenomenon. Nonlinear simulation in a full 3D geometry of a helical device, as is addressed in this study, has seldom been attempted so far. As a first approach for this attempt, we study a configuration with low magnetic shear [2]. 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. Spontaneous relaxation in the overall pressure profile is observed. At present, we are studying a heliotron configuration, which has a medium magnetic shear.

References

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